

ENERGY
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Technical Guide: PUE in Agriculture

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Technical guide: Productive Use of Energy (PUE) in agriculture

The provision of energy is key to the socio-economic development of rural areas. While energy is used for various consumptive purposes, from lighting and information access to comfort and entertainment, it is not sufficient by itself to trigger development in rural areas. Using energy for productive uses will generate income and therefore economic development.

The residential use of electricity improves the quality of life of the rural community while productive uses of energy (PUE) in rural areas lead to increased rural productivity, more economic growth, and a rise in rural employment.

Next to facilitating and stimulating socio-economic development, stimulating the use of energy for productive uses is essential to make the provision of rural energy a viable business.

The rationale behind promotion of productive uses in energy projects is therefore multi-layered:

- Productive use can maximise the economic and social benefits of energy access. Energy projects with productive use components are more likely to lead to rural economic development than projects that simply focus on the provision of electricity or other forms of energy.
- Incorporating a 'productive use' focus into energy projects makes them more likely to contribute to the achievement of the SDGs.
- Rural electrification projects with a productive use component are more likely to achieve economic sustainability. Enterprises that generate profits through electricity use have a higher ability to pay for energy services than private households who use electricity for purely consumptive purposes.

In line with the Alliance for Rural Electrification (ARE) and the National Renewable Energy Laboratory (NREL), the productive use of clean energy can be defined as **agricultural, commercial and industrial activities that generate income and are powered by clean energy sources. These activities increase productivity, enhance diversity, and create economic value.**

Productive use activities in rural settings primarily include:

- Use in local industries, such as agriculture, livestock and fishing
- Light manufacturing, such as welding and carpentry
- Commercial and retail activities, such as tailoring, printing, catering and entertainment
- Medium-scale production, such as small factories or intensive agro-processing.

This guide will focus on a number of applications of productive use of energy in the agricultural sector. The EC Acceleration team has significant experience of the other PUE applications and can be approached for more information. A separate guide focuses on commercial and retail activities.

Energy and agriculture

The agriculture sector does require energy services at several points in its processes. This energy can be in the form of mechanical energy, thermal or electrical energy.

Some of the most obvious areas where energy is needed in agriculture are:

- Land preparation/tillage
- Weeding
- Harvesting
- Drip-feed/sprinkler irrigation
- Grain milling
- Oil pressing
- Drying (fruits, vegetables, coffee, tea, meat, fish, spices)
- Smoking (fish, meat, cheese)
- Food and drink cooling (e.g. milk chilling/pasteurisation)
- Animal feed production (pellets) and packaging
- Ice-making (fish storage)
- Water heating (e.g. textile dyeing, separating nut kernels)
- Sawmilling
- Electric fencing
- Improved warehousing
- Fish hatcheries and fish farms (water circulation and purification)
- Lighting (e.g. to increase night growth in nurseries or chicken raising)

In this guide, we will discuss some of the energy requirements that can be met by renewable energy, either through localised mini grids or directly as standalone applications.

Irrigation

Approximately 95% of farmed land in Sub-Saharan Africa and 60% of land in South Asia relies solely on unpredictable seasonal rainfall to meet water needs. Around the world, there are more than 500 million farming households that could benefit significantly from adopting irrigation technology. Solar water pumps have the potential to increase yields by as much as two to three fold depending on crop and climate.

Solar water pumps also expand seasonal growing cycles and mitigate periods of low or irregular rainfall. This, in turn, provides households with more predictable and disposable income to pay for education and save for emergencies, thereby reducing vulnerability to risks. Beyond these social and economic benefits, solar water pumps can significantly reduce irrigation-related environmental damage. They can achieve a similar level of performance as diesel pumps without the carbon emissions associated with fossil fuels and can reduce farmers' water consumption when used in conjunction with more efficient irrigation techniques. The use of solar water pumps also helps farmers become more resilient to natural disasters, especially droughts and other changes in rainfall patterns.



Figure 1 Solar water pump, Source: Celfre

With advances in solar technology reducing costs, pump manufacturers' increased interest in smaller applications and increasing numbers of pumps tailored for small scale use in the market, there is now a growing business case for smallholder farmers to adopt solar water pumps. There are now more products available tailored to smallholder farmers. While the upfront costs are typically still higher than equivalent diesel pumps—the average entry-level diesel pump starts at USD \$200 compared to approximately USD \$600 to \$800 for a solar equivalent—solar water pumps have lower lifetime costs.

	SUBMERSIBLE PUMP - LARGER	SUBMERSIBLE PUMP - MICRO	SURFACE PUMPS
			
DESCRIPTION	Fixed pump and PV panels, tailored installation	Semi-fixed pump and PV panels, guided installation	Mobile pump and PV panel, guided installation
TECHNICAL SPECS	3-5 HP. Maximum suction lift of 350m	Works on a 160-260W panel, with a flow rate of up to 3,000 liters/hr. Maximum suction lift of 65 meters.	Works on an 80-120W panel, with a flow rate of up to 3,600 liters/hr. Maximum suction lift of 7 meters.
STARTING PRICE (BRANDED)	3,500 USD	650 USD	695 USD

Figure 2 Overview of types of submersible and surface pumps, Source: Solar Water Pump Outlook, 2019.

Given the high upfront costs of solar water pumps, an expansion of financing options and approaches is needed to unlock growth. Financing products must respond to farmers' needs. For example, farmers earn income at certain time(s) of year when they harvest produce. Pay-as-you go (PAYG) financing options can be designed to match growing cycles for specific crops. In collaboration with local financing institutions (either e.g. commercial banks or government extension services), leasing, asset loans and off-taker structures could be explored to make the pumps more affordable to the farmers.

With the smaller portable pumps being equipped with telemetry to monitor the technical condition of the pumps, the opportunity to introduce PAYG payment methodologies can open the market to those small holder farmers that are not able to finance the full upfront costs of a solar water pump.

Next to the upfront investment required, another barrier to the uptake of solar powered water pumps is a lack of knowledge and trust in the technology among farmers. Particularly the latter can be overcome by long term warranties, such as the five year warranty on the Future Pump SF2 model.

Milling

To prepare cereals for further processing, chaff must be separated from grain, either manually with a winnowing tray or mechanically by a powered shaker or grinder. Mechanical power is also available for de-husking rice or shelling maize as an alternative to manual work with rice hullers or huskers and maize shellers. The same applies to other cereals and crops for which special machinery has been or is being developed. Bran as a by-product of dehulling cereals is a source of income if sold as poultry feed and other animal feed.

Milling transforms grain into flour for food preparation. The main crops that are milled are maize, rice, sorghum, teff and millet, using hammer or plate mills. A hammer mill crushes aggregate material into smaller pieces with hammers (beaters) made from hardened alloy steel which are rectangular for efficient grinding. Hammer mills are also used to pulverise by-products of coconuts (copra), palm kernels and other oil seeds (press cake). Wheat is milled with roller mills but these are too expensive for small-scale operations. Although demand may be highest during the harvest season, grain milling is required throughout the year as many households keep a stock of grain.



Figure 3 Solar grinding mill, Source: Agsol

Category	Diesel mill	Electric Mill	Retrofit Mill	Solar Mill
Details	Driven by a diesel-powered engine which is coupled to the mill.	Driven by an AC induction motor coupled to the mill via a belt	The existing mill's diesel engine is replaced with an electric motor	Driven by a solar PV system powered AC or DC motor
Availability	Most common in areas without electricity	Most common in electrified areas, also used on mini grids	Not common. It is being piloted by JUMEME ⁴² on their mini grids in Tanzania. ⁴³	Not well developed
Power Rating (kW)	7.5 – 17.5 kW	7.5 – 15 kW	7.5 – 15 kW	1.5 – 2.2 kW
Estimated Cost (USD)	1,000	2,000	500 ⁴⁴	2,500
Average Throughput (kg/hr.)	120-150 ⁴⁵	120 - 150	Currently not available	32 ⁴⁶

Figure 4 Available milling options, Source: Solar Milling: Exploring Market Requirements to Close the Commercial Viability Gap, 2020.

For the majority of Sub-Saharan African communities that rely on grains and cassava as their main staple food crop, milling is a crucial processing activity. In rural off-grid communities, diesel powered mills are commonly used to displace the need for manual grinding and pounding. Diesel mills have relatively low capital costs and a well-developed supply chain for repair and maintenance. However, diesel mills have high operational costs, are difficult to operate, are less reliable than electric mills, run on engines that pollute the environment, and are not always placed close to their intended users. This also increases the time and labour burden for women and children, who are often tasked with food processing.

In areas with the right topography and water runoff, such as around the border between Zimbabwe and Mozambique, numerous hydropower driven grinding mills do exist. If this hydro resource is available,

these water powered mills are the preferred choice. In fact, during periods when no milling takes place, the hydro resource can be used to generate electricity for local mini grids.

Where hydropower is not available, electric mills equipped with either alternating current (AC) or direct current (DC)/Brushless DC (BLDC), motors powered by mini grids or stand-alone solar photovoltaic (PV) systems offer an alternative to diesel mills. Electric mills are reliable, easy and cheap to operate, environmentally friendly and properly sized to allow more distributed placement, reducing the time and labour burden associated with accessing milling services.

In general, the viability of electrical mills in mini grids is well understood. However, the actual processes involved to get owners of diesel powered mills to switch to electrical mills is less straightforward. Mini grid operators would like to see diesel grinding mills replaced by electrical mills as these can provide meet daytime electricity demands. However, mill operators, although they might understand all the benefits of electrical milling above diesel milling, are very reluctant to make the shift as they have doubts whether the mini grid can power their equipment as and when they are needed. Careful collaboration and identifying first movers are essential in this respect.

Technical advances in electrical milling might help mill operators move away from diesel grinding. The Mini Grid Innovation Lab, a joint initiative by CrossBoundary and The Rockefeller Foundation, is currently working with mini grid operators to develop an electrical grinding mill that is outperforming diesel mills and delivers the quality of flour customers prefer. Based on existing Chinese-manufactured electric grinding mills, they have improved energy efficiency, increased performance and are adjusted to better match local customer expectations. If the current prototypes are successful, the Lab will open-source the design specifications of these mills, and start working with additional distributors and manufacturers to scale production of electric mills ready for the off-grid market.

Next to this, stand-alone grinding mills powered by solar PV are becoming more and more affordable and available and do provide good opportunities to start new businesses. If coupled with favourable financing plans, a substantial market does exist.

Milk chilling

Chilling and cooling is an integral part of many agro-processing value chains to ensure produce can be kept fresh. In this section, we discuss the chilling of milk to reduce losses in the value chain. For other chilling applications, the EC Acceleration team can be approached.

In most developing and newly industrialised countries, raw milk is not cooled at farm level. As a result, quality of (evening) milk is lost because it doesn't survive the heat overnight. Low quality (evening) milk is then rejected by collection centres. While there is a growing domestic demand for milk of higher quality and larger quantities, 85% of the produced milk is not processed, and 30-50% goes to waste.

VARIABLE	VALUE	UNITS
Size of diesel power motor	15	horsepower
Diesel consumption per hour	3.2	liters (L)
Diesel price	0.99	\$/L
Operational hours per day	2	hours
Cost of diesel per day	6.34	\$/day
Size of equivalent electric motor	10	kW
Amount of power consumed per day to match the amount of maize milled per day	20	kWh
Equivalent micro-grid tariff required to compete with the cost of milling using a diesel engine (\$6.34/20kWh)	0.32	\$/kWh

Figure 5 Energy pricing comparison for maize mills, Source: Productive Use of Energy in African Micro-grids, 2018.

Chilling facilities at farm level can alleviate this problem. For small holder farmers with up to 10 dairy cows, a storage of 10 litres can allow the majority of these farmers to keep evening milk fresh till the next day.

Table 1 Active support programmes for productive use of energy

Programme	Main activities
The Green Mini Grid Help Desk	Funded by the Africa Development Bank as part of the Green Mini Grid Market Development Programme (GMG MDP). Mini grid developers receive technical assistance, from support on demand assessments to technical sizing, capital raising, procurement and installation support, commissioning, and optimisation of operations.
Efficiency for Access Research and Development Fund	Funding into research and development (R&D) projects with the aim to accelerate the availability, affordability, efficiency and performance of a range of low energy inclusive appliances that are particularly suited to developing country contexts and promoting social inclusion.
Innovations Against Poverty	Through financial and non-financial services, IAP supports innovative Inclusive Business models that deliver commercial benefits for the private sector and developmental benefits for the low-income population, while paying specific attention to gender equality and environmental sustainability.
Global LEAP Awards	The Global LEAP Awards use a competition-based approach to drive innovation and performance in early stage product markets for off grid applications, while also building valuable technical and commercial market infrastructure. Awards results serve as core market intelligence for investors, donors, policymakers, solar distributors, and other off-grid market stakeholders.
Low Energy Inclusive Appliances (LEIA) Programme	The Low-Energy Inclusive Appliances (LEIA) Programme is a research and innovation programme that seeks to double the efficiency and halve the cost of a range of electrical appliances suited for off- and weak-grid households, small business, and industrial consumers. The programme delivers a range of activities to stimulate the sector, including five principle components that address key market barriers: <ol style="list-style-type: none"> 1. Market Stimulation and Incentives 2. Testing and Quality Assurance 3. Marketplace Education, Communications, and Coordination 4. Market Intelligence and Technology Road Mapping 5. R&D Co-investments
Energising Development (EnDev)	EnDev promotes sustainable access to modern energy services for households, social institutions and small to medium-sized enterprises in developing countries in Africa, Asia and Latin America. The supported energy services meet the needs of the poor, i.e. they are long-lasting, affordable, and appreciated by users.

Farmers not reached by either the national grid or isolated mini grids will need to look into standalone applications. Several projects and programmes have looked at this issue, resulting in a number of technologies being developed ranging from cooling with solar PV (with ice as an intermediary cold storage) to small scale biogas-run chillers. With all these technologies, the affordability for the small scale farmers is a major stumbling block. Innovative business models and financing options need to be developed for this.

Industry associations

No specific association exists that looks at productive use of energy in general or in agriculture specifically. However, the **Alliance for Rural Electrification (ARE)** is a good starting point for productive use of energy in rural electrification projects. For standalone applications, the **Efficiency for Access Coalition** can be approached.

References and further reading

EEP Africa Powering Productivity

https://eepafrica.org/bfd_download/productive-use-of-energy-study/

EUEI PDF / ARE - The Productive Use of Renewable Energy in Africa

<https://www.ruralelec.org/publications/productive-use-renewable-energy-africa>

Productive Use of Energy (PRODUSE) - A Manual for Electrification Practitioners

http://www.produce.org/imglib/downloads/manual/euei_productive_use_manual_med.pdf

Productive Use of Energy in African Micro-Grids – NREL

<https://www.nrel.gov/docs/fy18osti/71663.pdf>

PU Value Chain Mapping Report by E4I

https://greenminigrid.afdb.org/sites/default/files/pu_mapping_for_minigrids_in_africa_february_2019.pdf

Toolbox on Solar Powered Irrigation Systems

https://energypedia.info/wiki/Toolbox_on_SPIS

2019 Global LEAP Awards Buyer's Guide for Solar Water Pumps

https://storage.googleapis.com/leap-assets/2019-Global-LEAP-SWP-Buyers-Guide_final.pdf

Solar Milling: Exploring Market Requirements to Close the Commercial Viability Gap

https://storage.googleapis.com/e4a-website-assets/SolarMilling_Market-Requirements.pdf

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